USDA GLOBAL CHANGE STRATEGIC PLAN

United States
Department of
Agriculture

U.S. DEPARTMENT OF AGRICULTURE

GLOBAL CHANGE

STRATEGIC PLAN

October 1990

946211

GLOBAL CHANGE STRATEGIC PLAN

PREFACE

What Is Global Change?

The Earth is a place of change. The geological record testifies that the Earth's environment has been subject to change over eons—much of it occurring slowly over many millennia, but some relatively rapidly over decades. The changes are in response to such phenomena as the migration of continents, the building and erosion of mountains, the reorganization of oceans, the orbital relationships of the planets to the Sun, variations in solar output, and even the catastrophic impacts of large meteorites. The underlying causes lead to changes on local, regional, and global scales: a succession of warm and cool epochs, the appearance and disappearance of large deserts and marshlands, new distributions of forests and rich grasslands, advances and retreats of great ice sheets, rising and falling sea and lake levels, and the extinction of vast numbers of species.

Although these changes are the inevitable result of major natural forces beyond human control, it is apparent that a relative newcomer to the scene—the human being—has now become a powerful agent of environmental change. The chemistry of the atmosphere has been altered significantly by agricultural and industrial revolutions. The development of water resources has affected patterns of natural water exchange in the hydrological cycle. As world population grows and the world undergoes further technological development, the role of humans as an agent of environmental change will undoubtedly grow.

Environmental changes are the result of complex interplays among a number of natural and human-related systems. For example, changes in the Earth's climate involve not only winds and clouds in the atmosphere, but also the interactive effects of the biosphere, ocean currents, human influences on atmospheric chemistry, the Earth's orbital characteristics, the reflective properties of the planet, and the distribution of water between the atmosphere, surface water, and surface ice. The global aggregate of interactive linkages among the major systems that affect the environment has become defined as *global change.*

Environmental change has always been a major consideration of the U.S. Department of Agriculture (USDA). Adapting plants and management strategies to cope with changes in moisture, temperature, light, and soil variability requires knowledge of how specific plants and animals respond to change. USDA must be capable of assessing short-and long-term effects of potential global changes on all aspects of American agriculture and forestry. The Department must also be able to assess how agriculture and forestry affect the global environment. USDA cooperates with other agencies of the U.S. Government through the Federal Coordinating Council for Science, Engineering and Technology (FCCSET) Committee on Earth and Environmental Sciences. This planning enables multidisciplinary scientific research that can provide knowledge and technology to agriculture and forestry. USDA also participates in international research and planning

Concentrations of atmospheric carbon dioxide and certain other trace gases and of tropospheric ozone, and intensity and quality of ultraviolet light have long been regarded as constant in animal and plant physiology models. Human activities have apparently transformed the constants into variables. Research is needed to determine how these now-variable factors affect animals and plants. Also, systems for measuring how much ultraviolet-B (UV-B) radiation actually reaches the Earth must be put in place.

USDA recognizes that food and fiber production, processing, storage, and transportation activities add carbon dioxide and trace gases to the atmosphere. USDA also recognizes that some measures to forestall potential changes to the environment must be started immediately while research on long-term consequences continues. Many of the short-term measures are the kinds of management activities that help sustain U.S. agriculture and forestry and would be important in any case. Such activities include afforestation, reforestation, minimum tillage, and increased crop residue use, for example. Much remains to be done. Especially needed is knowledge about the linkages between plant and animal physiology and the ecosystem, between the ecosystem and management, between management and the costs and benefits, and between costs and benefits and agricultural policy.

Existing research programs provide a firm foundation for developing this knowledge, but new programs are also needed to develop the understanding required to prepare for future challenges.

U.S. DEPARTMENT OF AGRICULTURE
GLOBAL CHANGE
STRATEGIC PLAN

I. INTRODUCTION

Objective

The objective of this plan is to establish a long- term strategy for research, education, technology transfer, extension activities, and policy analysis to assist in sustaining U.S. agriculture and forestry compatible with future global changes.

USDA's research, education, and technology transfer system consists of a professional Federal research staff working in a close partnership with the Land- Grant universities, State forestry schools, and State agricultural and forestry experiment stations. The research system is closely linked to State and Federal technology transfer and continuing education agencies to provide technical assistance for the management of this Nation's private lands and directly manage a significant portion of its public lands.

USDA Role

USDA conducts research to assess how global change affects U.S. and international agriculture and forestry and how agriculture and forestry contribute to global change. Included are basic research on biological responses to increasing greenhouse gases and tropospheric ozone, improvement of plant and animal germplasm to adapt to global change, and development and implementation of plans for systems to mitigate increases of greenhouse gases. An additional responsibility is research on applications of agricultural meteorology to improve agricultural and forest management decisions.

Through its interaction with the global change working groups of the FCCSET Committee on Earth and Environmental Sciences (CEES), USDA coordinates its research planning activities to complement the research programs of other Federal agencies. Therefore, USDA not only helps meet the research needs of agriculture and forestry, but contributes to the overall U.S. global change research program.

USDA also participates in international global change planning and research. Individual scientists from Federal and State experiment stations are involved in the International Geophysical Biophysical Program, and scientific leaders serve as delegates to working groups of the Intergovernmental Panel on Climate Change.

New knowledge and new technologies developed at the Federal and State institutions are then transferred to the production sector through the State and Federal extension system. Policies that guide the overall food and fiber system are thus derived from the information base arising from this vast Federal-State-private system.

Issues

Agriculture, forest, and grazing management have always been subject to the vagaries of weather and climate. USDA research has long been directed toward discovery of relationships between weather variables, such as temperature and precipitation, and physical/biological mechanisms of ecosystems. Emphasis has been on understanding photosynthesis and evapotranspiration and their dependence on soil nutrient levels, soil water content, air and soil temperature, and plant germplasm. This knowledge has underlain the management strategies that make U.S. agriculture and forestry the most productive in the world.

- New environmental factors must now be taken into account. Rising levels of carbon dioxide could result in substantial increases in yield and water use efficiency of crops.

Increased air pollution and acid rain have received considerable attention from USDA scientists during the past 10 years. Atmospheric carbon dioxide, methane, nitrous oxide, tropospheric ozone, and UV-B radiation intensity must now be considered to be environmental variables, since they are no longer the constants they were considered to be for so long.

- Manipulation of the levels of the new variables combined with temperature and rainfall pattern are potential problems for sustaining forest and agricultural production systems. Although the carbon dioxide concentration of the Earth's atmosphere is predicted to rise substantially in the next few decades, the impact that this and changes in levels of trace gases will have on the Earth's temperature is not certain. Because world food storage capacity is limited (90 - 180 days), any increase in annual climate fluctuation is a potential problem.

- The effect that these changes will have on global atmospheric circulation patterns and regional precipitation distribution is even less certain, although an overall temperature increase would logically result in an average increase in rainfall over the Earth's surface. An increase in temperature may increase the rate of evapotranspiration. Yet, if precipitation increases, the climate will become wetter, and cloudiness will become greater, so evapotranspiration may not be affected. Regional variability is a virtual unknown.

- Understanding future scenarios different from any past experience requires a new research philosophy for USDA. The future can no longer be extrapolated from the past. Models of future systems must be constructed and manipulated to determine sensitivity to changes in variables.

- Our inability to accurately predict the future environment of each agricultural and forestry production region does not mean that USDA can wait until change occurs to develop a response strategy. Critical resources and production systems, along with food, fiber, and water supplies, require alternative strategies if they are to be sustained in the worst possible cases.

- Information and education programs will be instituted in a timely manner to convey to land managers and users how they can help limit and mitigate gaseous emissions. Meanwhile, research will continue to develop a more comprehensive understanding of the long-term effects of those emissions and how to adapt to possible changes resulting from the increased atmospheric greenhouse gas composition.

- USDA must start now to evaluate current technology and develop new technology that will enable our use of crop and forest products as energy sources. Technology must also be developed which allows such uses with minimal change to the environment.

Program

USDA's global change strategic plan has two basic parts: (1) the effect of global change factors on forest, pastoral, and agricultural ecosystems, and (2) the effect of the forest, pastoral, and agricultural ecosystems on factors that influence global change.

The strategic plan is divided into sections on research, data management, education, assessment and policy, and responses. Research strategies are based on the elements of the U.S. Global Change Research Plan. The priority for USDA differs slightly from that for the national plan. "Ecological Systems and Dynamics" is a higher priority for USDA, whereas the Global Change Research Plan identifies "Climate and Hydrologic Systems" as highest on its list of priorities.

Past research has enabled agriculture and forestry to adapt to different climate regimes and to increase production capacity. Such related programs as development of plant varieties and animal breeds, genome mapping, and genetic engineering will continue to contribute to the adaptive ability of agriculture and forestry.

Developing alternative pest management systems will contribute to the Department's global change program. New commodity storage and food processing technologies under joint State, Federal, and private development will help U.S. agriculture and forestry adapt to long-term change and will help minimize agricultural contributions to such change.

USDA assessment and monitoring programs have provided some of the most comprehensive data available on land use shifts and current production capacity. The strategies presented in this plan are designed to augment existing programs to meet the future needs.

Data management needs in the era of global change will challenge the most advanced levels of computer technology. USDA strategies will augment existing research in data and information management and support new programs where needed.

II. RESEARCH PROGRAM STRATEGIES

A. ECOLOGICAL SYSTEMS AND DYNAMICS

Research on ecological systems and dynamics includes study of how terrestrial and aquatic ecosystems respond to changes in environmental conditions. This research also examines the influence of biological communities on the environment. Research programs will include: (1) structure and function of biological systems during various time measurement units, (2) beneficial response of species, biological communities, and natural and managed ecosystems to increasing atmospheric carbon dioxide concentration, increasing UV-B radiation, and climate and physical/chemical stresses, (3) the interactions between physical and biological processes during various time periods, (4) modeling ecological and physical climate interactions, and (5) modeling plant and animal production in natural and managed ecosystems.

Monitoring

USDA already has several ecological data bases, which were developed and continue to receive data on experimental forests, ranges, watersheds, and farms. USDA will follow trends from these data bases and long-term monitoring sites for early indications of global change and to identify sensitive indicators of global change.

- USDA will determine which of these experimental farms, etc., should be contained in a national network of long-term sites for monitoring environmental change.
- USDA will establish a network of long-term monitoring sites to determine the health, productivity, and diversity of our agricultural and forest ecosystems.
- USDA will determine long-term trends in the response of agricultural and forest ecosystems, to assess effects, understand processes, and predict future changes resulting from environmental change.

Variables such as UV-B that may damage living organisms are currently not being monitored often enough or over sufficient areas. The geographic range of the monitoring network and the number of research sites will be expanded to provide the basis for assessing current effects, understanding processes, and predicting future effects.

Critical variables will be identified over a broad geographic range to assess agricultural and forest systems' response to change. The USDA programs will augment existing experimental forest, rangeland, and farm observation programs. Likewise, existing facilities will be maintained and modernized to accommodate long-term studies.

Agencies participating in the U.S. Global Change Research program will coordinate the management of ecology-related data. USDA will support a national and global network for managing ecology-related data, for establishing procedures, and for ensuring computing capability at a level compatible with the needs of the global change program. Remotely sensed data pose problems because of the large data volume. A systematic program of analyzing and archiving both old and new data will be developed in association with the proposed NASA Earth Observing System.

Research

Understanding how the changing environment affects forest, pastoral, and agricultural ecosystems, and conversely how these ecosystems affect atmospheric gas composition, is the principal goal of the global change program. Basic ecosystem processes that function in a

multiple-stress environment will be studied in both the laboratory and field. Research programs will focus specifically on:

- Response of individual organisms to air pollutants, carbon dioxide enrichment, and UV-B radiation intensity.
- Sensitivity of biodiversity and the inherent adaptability of plant and animal populations and communities.
- Responses of ecosystems and biological communities to land use changes and climate and chemical stresses, with particular emphasis on competition among individuals within the ecosystem. This includes aquatic and terrestrial ecosystems.
- How episodic events, such as pest infestations and fire, saltwater intrusions, and soil erosion, influence ecosystems.
- Relationships between ecology data bases at regional and global scales.

USDA will develop an understanding of ecosystems, from cellular-level processes to landscape processes, and of how these processes interact with atmospheric changes. These complex processes will require multidisciplinary research.

Model Development

To apply the knowledge acquired about individual organisms and ecosystems in strategies to manage agricultural and forest ecosystems, basic process models will be needed. These will be models of:

- Physical and biological processes and eventually of regional ecosystems involving these processes;
- Global change at the regional level;
- Ecosystems based on regional and global models of atmospheric change.

These models will be used to predict exchange of energy, moisture, etc., between the biosphere and atmosphere.

Ecosystem models are complex. As a consequence of genetic changes, uncertainties of pathogen effects, biological and physical stress, and other uncertainties, responses can never be predicted by deterministic models. Therefore, stochastic (probability indices of occurrences) outputs are needed from process models. Assessment of the future and prediction of yields, coupled with economic and risk analysis, will be the objective of this modeling effort.

Limitaton and Mitigation

Research programs to limit or offset impacts of UV-B on ecosystems will be developed in future stages.

B. BIOGEOCHEMICAL DYNAMICS

Carbon, nitrogen, oxygen, sulfur, and phosphorus are major components of biogeochemical cycles. The key compounds of greatest concern to managed ecosystems are carbon dioxide, methane, and nitrous oxide. The major reservoirs for these gases are the oceanic and fresh water aquatic systems, the solid earth component, the biosphere, and the atmosphere.

Understanding what controls the biogeochemical cycles is the scientific basis for policy decisions.

Monitoring

Establishing the magnitude and spatial and temporal variation of carbon, nitrogen, oxygen, sulfur, and phosphorus reservoirs allows us to define the total content of these elements in the global system and their ambient distribution. USDA will develop long-term observations of land reservoirs, their component parts, the quantitative trends, and distribution changes.

- Long-term ecological research sites. USDA will participate in making observations on these sites to monitor and model trends in gas fluxes. Educational potential will be considered in site selection. A coordinated interagency effort will be devised for selecting USDA long-term ecological research sites and for determining how these will be instrumented and managed. These sites will be located where possible within existing or proposed sites of the Long-Term Ecosystem Research Network, partially funded by the National Science Foundation.

Research

Changes in the processes controlling geochemical (carbon, nitrogen, oxygen, sulfur, phosphorus, and heavy metals) fluxes cause subsequent changes in the amount contained in the resource base. While some chemical transformations are known, other transformations are not known with much certainty. While biogeochemical cycling can induce global changes, such changes can also alter biogeochemical cycling.

Research to understand the processes influencing these fluxes will include:

- Carbon dioxide from soils and biomass. Research will continue to clarify the contributions of carbon dioxide from organic decomposition and combustion. Additional research will focus on the carbon uptake capacity of below-ground biomass and soil carbon storage.
- Methane from vegetation and livestock systems. Research programs will focus on defining the anaerobic processes generating methane and developing technology to limit these emissions on a unit by unit basis. Additionally, studies focusing on methane fluxes to and from forest soils will be studied.
- Nitrous oxides in the soil and relationships to fertilizer. Research will continue to describe the processes of denitrification from chemical and organic nitrogen sources and develop methods for balancing the total nitrogen budget.

Grant research programs will augment understanding of the mechanisms of methane generation and will focus on developing the capability to reduce the amount of methane emitted by agriculture, if necessary. Other components of the trace gas program involve energy conservation (including studies on external combustion engines), biomass fuel use to reduce airborne pollutants, and plant responses to trace gases.

Grant programs will augment work begun in Fiscal Year 1989, which acquires basic information needed to assess, predict, and manage the effects on agricultural crops from ozone depletion. The program will encourage research in plant interactions with a variety of environmental factors. UV-B monitoring will be included as a replacement for the National Acid Deposition Program network, which is being phased out.

Existing research programs in aquatic ecosystem methane fluxes and nitrous oxides will be augmented. Research will also focus on how the aquatic environment influences reproduction, growth, and survival of individual species, and how different levels in the food chain respond to environmental stress. This research will also focus on determining the annual uptake and emissions of such gases.

Model Development

Models are required to provide scientists with an understanding of the dynamics of the biogeochemical fluxes and systems.

- Models will be used to predict differences in the geographic distribution of trace gas reservoirs. Regional models will be developed to utilize the output of global models. Ongoing USDA and university research in many areas of nutrient cycling will be augmented for the development and validation of models.
- Methods will be devised to model the entire methane and nitrous oxide cycles. One clearly missing link is the interaction between sulfur biogeochemistry and the carbon and nitrogen cycles. Strategies will be developed to expand support for research currently contributing to answering this question.

C. CLIMATE AND HYDROLOGIC SYSTEMS

Monitoring

Water vapor is the primary greenhouse gas. Understanding how global change will affect the hydrologic cycle and, in turn, how changes in the hydrologic cycle affect such things as atmospheric water content (including clouds) is critical to predicting global change effects. Strategies must be developed either to measure the critical variables affecting the hydrologic cycle or to infer their values from variables that are measured.

Long-term hydrologic observations establish baselines from which changes in hydrologic variables can be measured over time. These variables include precipitation, evapotranspiration, soil water infiltration and storage, stream flow, runoff, drainage, and reservoir storage. Other variables, such as temperature, solar radiation, relative humidity, and wind, are included in the observations for completeness. All are necessary parameters to validate process-oriented simulation models designed to predict how global changes will affect hydrology.

Several long-term hydrologic observation programs exist within USDA. Stream flow observations to measure water yield and water quality on managed and control watersheds have been made on more than 70 USDA experimental watersheds in forest, steppe, and agricultural ecosystems. Fourteen experimental watersheds are in operation, with data records from several of them exceeding 50 years' duration. A network of 1,700 monitoring sites in the Western United States have measured snow depth and snow water content for more than 50 years; nearly a third of these sites have been monitored automatically for the past 10 years as SNOTEL sites. Information on soil hydrologic properties is also maintained on 16,000 soil series and 60,000 soil units in the United States and on 600 soils worldwide.

Data collected in these long-term observation programs provide a critical historical foundation. But they cannot provide a data base that is adequate to meet the expanding research demands for predicting the future global environment. The following strategies will be implemented to meet growing data needs:

- Produce and distribute a complete inventory of existing USDA climate and hydrologic data to all participants in the Global Change Program.
- Determine the need for specific sets of existing USDA data by climate modelers and other Global Change Research participants, and make essential data sets available to them.
- Define in these data bases critical gaps that are of sufficiently high priority to be filled.
- Determine the most effective means for filling critical gaps in remote sensing and automated recording stations.

Research

- Vegetation Reflectance Index. For terrestrial vegetation reflectance indexing, USDA programs will be extremely important to ground-based support for satellite monitoring efforts. USDA and its partner State institutions will augment ongoing studies of the use of vegetative reflectance indexing for many agricultural and forestry problems, particularly those associated with food and fiber production, ecosystem changes, water uses, pollution, insect and disease problems, animal migration, and land uses. Interagency coordination strategies for vegetative indexing will be established.
- Precipitation. It will never be possible to measure precipitation at time interval and geographic densities required as input for models ranging from fields to watersheds.

Because research conducted by other Federal agencies is not adequate to meet the needs for agriculture and forestry, USDA will develop strategies to provide the needed input data, including developing algorithms that take into account regional effects of mountains and other physical factors. Historically, this lack of data has hampered the ability to accurately forecast weather variability for farmers and foresters. These variability functions will be used to infer precipitation at times and locations beyond the existing measurement network. Included within these strategies will be the use of vegetation responses as a means of estimating precipitation.

- Evapotranspiration. Research directed toward predicting evapotranspiration to the atmosphere from agricultural and forest ecosystems, at field and regional scales, will be closely linked with the development of ecosystem models. Incorporation into models of the direct effect of atmospheric carbon dioxide concentration on distribution and composition of vegetation in both forests and agricultural ecosystems is particularly important. Evapotranspiration from crop, forest, and range lands depends on the condition of the vegetative cover, and on the infiltration, storage, and water transport attributes of the soil. These data will be linked to data gathered by other agencies, and will be used in USDA models.

- Soil moisture. Content of water in the soil and the capacity to hold moisture are critical variables in predicting vegetation condition and productivity, runoff, soil erosion, water recharge to aquifers, and evapotranspiration. Measurement by traditional manual means is too costly to acquire sufficient density and timely data sets required by ecosystem models. Two basic strategies will be pursued to eliminate this deficiency: 1) Exploit recent developments for directly measuring soil surface moisture over large land areas with remote sensing, and 2) develop predictive models tc infer soil water status from measurements of other variables.

- Scale interactions—atmospheric. Not enough is known about how small-scale atmospheric processes, such as convection and cloud interactions with aerosols and radiation, affect larger scale climate processes or how large-scale climate processes affect small-scale events. There is no other global change research program that will focus at this level of detail. Research to improve understanding of the mechanisms linking processes at these two scales will include improved observations as well as development of theoretical models. Linkages will take place with the National Aeronautics and Space Administration and the National Oceanic and Atmospheric Administration as research progresses.

- Coupling mechanisms—atmosphere-land surface. We are unable to predict snow and soil frost distribution, in addition to soil erosion and evapotranspiration of crops and trees, using existing data and models. Research to provide climate-relevant predictions of time and space distributions of snow, frost, and other variables will involve synthesis of existing knowledge about the processes involved, controlled experiments to test hypothesized processes, and development of observation sets to establish the limits of variables and validate resulting models.

- Land surface reflectance. This variable is affected by the type and condition of vegetation, which is affected by soil water. Reflectance is also affected directly by surface soil water content, as well as by soil color, or by the extent and age of snow cover. Prediction of these factors will stem from existing models and from ecosystem models being developed in

other programs. The SNOTEL snow observation program, as well as existing modeling of snowmelt and runoff, will contribute to the prediction of snow reflectance.

- Atmospheric aerosol loading. Dust from range and agricultural lands contributes to the atmospheric aerosol load that affects the solar radiation balance. Current models of the wind erosion processes will be used as a basis for developing an aerosol-loading model.
- Water supply to streams and aquifers. USDA has the primary national responsibility for developing water supply forecasts, which it accomplishes by using U. S. Geological Survey (USGS) waterflow data bases. Precipitation not lost as evapotranspiration either is stored as soil water or snow, or flows to streams, lakes, or aquifers. The amount and timing of waterflow to each of these pathways are sensitive to climate. Research will build on existing models and will focus on developing an understanding of hydrologic response to changed climate and vegetation variables as a means of predicting the water supply.
- Erosion and reservoir sedimentation. Sedimentation resulting from upland erosion diminishes the storage capacity of water storage reservoirs. Research to quantify these changes in storage capacity for future climate and management alternatives will build on the multiagency Water Erosion Prediction Program (WEPP) being developed primarily to assess on-site impacts of erosion.

Model Development

No computer has sufficient capacity and speed to simulate the entire Earth as a single system. Therefore, submodels must be constructed to help predict responses at regional scales. The task of predicting the biological effects of both climate and non-climate environmental changes is complicated by interactions and fluxes among the various trace gases. Models will be developed at site and regional scales; these will be linkable so that larger scale interactions can be simulated.

- Water-partitioning distribution models. Models will build on existing field-scale vegetation models, but will focus on predicting the effect of vegetation on the partitioning of water into runoff, evapotranspiration, soil storage, or deep percolation. Changing climate, atmospheric carbon dioxide concentration, and UV-B radiation levels will be included as variables because they can alter not only the areal extent, but also the species distribution and condition of vegetation.
- Surface hydrology processes. Emphasis will be placed on integration of advances in the understanding of vegetation and surface hydrology processes from small-scale to large-scale models that can be used in climate studies. Models relating the interactions of meteorological and hydrological processes over relatively short times (minutes to days) and small- area scales (field to watershed size) are relatively advanced.
- GCM-ecosystem coupling models. Climate and hydrology models will be constructed to bridge the gap between general circulation models (GCM's) and ecosystems. Current general circulation models cannot provide input at regional, ecosystem, and watershed scales. Research models will include the effects of climate change so that regional climate stress effects can be evaluated as a basis for choosing mitigation and adaptation strategies.

D. HUMAN INTERACTIONS

Human activity, primarily since the beginning of the industrial age, has been the major factor in the increase in atmospheric composition of greenhouse gases. Basic research on the human contributions to global change is necessary to understand effects of (1) specific agricultural and silvicultural land use on the environment and (2) general structural and institutional causes of change in the Earth system, including such factors as economic markets and institutional systems.

Agriculture and forestry involve management by humans of the Earth's ecosystems for their physical, social, and economic well-being. How these systems are managed affect carbon dioxide sources of emission and mechanisms of uptake (sinks), nitrous oxide and methane emission, ground water and surface water use and quality, soil quality and erosion, and surface reflectance.

Research on "human interactions" will identify and predict changes in agricultural and forestry activities that will occur at a scale sufficient to affect global systems. The program will also predict how Earth system changes will affect rural communities, local and regional infrastructure, and national and global well-being through resource changes that affect agricultural and forestry systems.

Studies will build on existing research and understanding about the three general limitations to existing models of human interactions with natural systems. The first limitation stems from the strong tendency to view natural resource problems as local or regional issues. For example, existing global agricultural trade models do not include explicit links to the quality of the natural resources and resource base. The second limitation is the tendency to focus on short-term issues. This ignores or fails to recognize gradual and persistent natural resource and resource base changes in a context of changing technology and increasing food, forest, and fiber demand due to pressures from population and economic growth. Intergenerational costs of action must be taken into account. The third limitation results from accepting certain levels of quality—either of the natural resource or of the resource base—as unchanging or as varying around a historical mean.

Adaptation

Research will be conducted to further identify how management decisions on agriculture, forestry, and other land uses affect the adaptive capacity of regional systems and to understand how economic, demographic, social, legal, and institutional variables influence these adaptive decisions. Focus will be on specific adaptations of human activities influencing global changes.

- Research will be conducted on the degree to which agriculture and forest systems contribute to total human-related emissions of trace gases and on the ability of alternative agricultural and forest system technologies to reduce emissions, and will provide estimates of how much reduction can be accomplished.
- An assessment will be made of the capability for technological change in agriculture and forest management systems to provide timely adaptive strategies to whatever effects result from global environmental changes.
- The relationship between human adaptations to global change and effects on the environment (through changes in forest and agriculture management systems) will be developed

and included in economic analysis of the total effect of global change on the human environment.

Monitoring

- Methodological research. Nationally based data, mostly based on samples of population, must be reconciled with unsampled population data to provide complete coverage of rural areas. Methods to integrate economic, demographic, and land use patterns will be developed.

- Human response to environmental change. Long-term surveys of human attitudes about global environmental change will be carried out. Surveys and measurements will be standardized with social surveys in other nations. The objective is to construct a comparable, cross-national data base, including perceptions of environmental change and individual, institutional, and governmental responses (i.e., adaptive strategies) to environmental change.

- Land Use patterns. Land use will also be a principal measure of the response of humans to global change. Long-term, continuous measurements of land use patterns are necessary to track global change and understand human response. Reconstruction of data on historical land use patterns is required including long- term measures of forest and other vegetative cover, agricultural production uses, and human settlement. A data base that integrates demographic, economic, and land use patterns will be used to develop predictive models to simulate future possibilities.

- Agricultural and forest production, production practices, input use, and price data. Standardized surveys of agricultural and forestry production practices, production, energy consumption, trace gas emissions, and economic data on prices will be developed.

Research

Research will seek to further understand how agriculture, forest, and other land use activities affect global systems, to improve the quantitative estimates of known effects, and to understand the people-related factors that affect these activities. Focus will be on specific types of human activities contributing to global change and on the relationship among these activities. These include:

- Emissions of trace gases from agricultural and forest systems. Emissions of trace gases (methane, carbon dioxide, and others) will be characterized by agricultural and forestry activity. Understanding the processes of these emissions will lead to strategies for mitigating their effects.

- Multiple threats. Human activity in responding to various threats—such as insect or disease outbreaks, drought and others—influences biogeochemical cycles and water quality and has other effects on the environment. USDA will study how these human activities modify the environment.

- Water resources. Water policies directly influence the amount and quality of water available for agricultural systems. Forestry practices also influence the amount and quality of water. USDA will study the effect of various water management strategies on quality and quantity of water in order to develop a policy for water in a changed environment.

- Risk assessment. Assessment will be made of human decisionmaking activities in the face of potential global changes related to agricultural productivity and diversity and forest health and productivity.
- Economics. An understanding of how global change may influence commodity prices and markets, both domestically and internationally, will include legal and trading processes.
- Production models. Models of agriculture and forest production, resource availability, and noncommodity uses will be developed.
- Economic models. Models of agricultural and forest economic systems will be developed from the local to the global scale.

E. EARTH SYSTEM HISTORY

Soils are the time-sensitive skin of the earth. A soil forms as the result of interaction of climate and biota—as modified by local topography—with the exposed parent materials through some period of time. (Soil parent materials are those earthy materials at or near the Earth's surface that are altered by the above processes into a recognizable sequence of soil horizons with characteristic physical, chemical, and biological features.) Periodic and random fluctuations in these soil-forming factors determine the magnitude of changes within soils and their distribution. There are alternating periods of landscape instability, during which major erosion and deposition occur, and landscape stability, during which vegetation succession and soil development proceed. The alternating processes of formation and degradation leave their marks in soil profiles everywhere.

Geologic formations exposed and available for transformation into parent material and soils range in age from Pre-Cambrian (550 million years ago) to very recent deposits of volcanic ash and river alluvium. But soils are younger than the materials in which they form. In fact, they record time according to the evolution of landscapes; thus, a few soils and surfaces are Pliocene (15 million years ago) in age but most are Pleistocene (2 million years ago) and Holocene (10,000 years ago to the present). The influence of climates and the direct and indirect effects of glacial and interglacial events throughout the Pleistocene era were global in extent, and much of this is recorded in world soil properties and distributions. Knowing what to interpret and how to read these paleo-soil records is the challenge of Earth system history research.

Understanding this historical record may aid us in predicting the soil's response to future climatic changes. Through models, we can then begin to predict the responses necessary for sustaining an area's agricultural productivity or otherwise ameliorating the effects of climate change. Buried soils and polygenetic soil features occur in most environments. Erosion of soils within a watershed, as opposed to burial of soils in the lower reaches of a watershed, are repeating phenomena. This indicates that many landscape-altering events are periodic, so models must be able to handle the jumps and intermittency of local, regional, and global events that influenced the phenomena. USDA will focus specifically on:

- Identifying significant environmental changes that have taken place, the extent of landscapes affected, and the effects on the soil profiles in order to calibrate our understanding of processes and their resulting impact on the soil.
- Determining landscapes and soils where changes of climatic conditions might be expected to have significant impact on natural and managed environments.
- Conducting studies in conjunction with scientists of other agencies on ecosystems expected to be sensitive to global change.

Research

An understanding of time periods and sequences of soil development as influenced by climate is being developed and refined by other scientists, and soil time markers for correlating events are provided by radiocarbon dating and uranium-thorium dating for the most part. A general scheme of characteristic times for the formation of certain soil features is available but needs considerable validation and further calibration to be useful for extrapolation to larger areas necessary for global modeling. The strategy of this soil-related research is to:

- Develop an improved framework for integrating the evolution and development of the soil into the history of the Earth system.
- Provide an improved framework by developing soil time formation periods in selected pilot areas.
- Work in pilot areas to provide working methods for calibrating models in other areas.
- Begin a network of sites whose models can be linked for regional extrapolation.

Model Development

A hierarchy of soil formation models will result from site studies, since many of the measurements will include internal soil features such as color, structure, concretions, translocation of clays, and organic matter. These will provide the basis for understanding how soil processes will respond to global change. Geographic distribution of soil horizons in landscapes (soil stratigraphy) will lead to geologically related soil-forming processes and distribution patterns that hopefully can be associated with causes and effects of climate-driven changes. Currently, very few mathematical models are available, and none that readily handle the variations from soil profiles at sites, to fields, to small watersheds, and beyond. Thus the strategy for developing predictive capability is as follows:

- Coordinate, test, evaluate, and refine soil formation models that can be shared in regions of the United States and parts of the entire continent.
- Develops chronology of soils similar to the chronology of geologic materials and events. Important products will be maps and reports dealing with the extent and kinds of soils chronologically and in a geographically dispersed manner.

III. DATA MANAGEMENT

Data management is essential for support of the U.S. strategy for research and education on global change. Success of the scientific research and resource assessments will depend on the quality of the data management and information system created to support the global change program. In this system, data must be transformed into information, and information into knowledge. Data from monitoring global change must be collected and made available to researchers who will sort, select, and summarize it, creating useful information. As researchers gain understanding of global change and develop predictive models, the assessments will distill their research, transforming it into knowledge useful to policymakers in dealing with the problems of global change. At the same time, the assessments refocus data collection and research into areas that address specific policy questions.

Information Systems

The goal of a strategic plan for data management will be the creation and maintenance of an integrated information system that will enable researchers, educators, policymakers, producers, and the public to access all relevant information in carrying out their responsibilities. Among the major elements of a global change information system are the data systems created by monitoring techniques for adding value to the data, communications, and means for relating these components into an integrated system.

- Data systems. Data systems exist in every scientific area of investigation in the global change program, and new ones will be created as a result of research. They will contain data in various forms: numeric data, images, citations to published research and to work in progress, and the full text of unpublished documents as well as formal publications. The data will be stored in various formats and in different media, from magnetic tape to CD-ROM. One of the critical challenges for managing USDA data will be coordination of data from specific research—such as responses of crop varieties to stress, data on erosion prediction, etc.—and spatial data that show location, extent, and properties of ecosystems, soils, and vegetation communities.

  It will be necessary to identify and describe in some detail the content and format of relevant data systems within USDA, and to obtain information about other U.S. and foreign data bases from the appropriate coordinating committees and other sources. As soon as possible, directories and data dictionaries will be created as guides for researchers and managers, culminating in a comprehensive inventory of all relevant data systems. This process will make it possible to identify gaps in the kind of data being collected, leading to the develop ment of more effective monitoring activities.

- Systems for increasing value of data. It will be necessary to investigate computer systems presently or potentially of use in processing or displaying data. These might include statistical software and model algorithms for analyzing data and for making predictions; expert systems (embodying the rules and methods experts use in making spatial judgements and decisions based on data); and geographic information systems, in which data from numerous types of observations can be displayed singly or overlaid and analyzed.

  Value can also be added to text files through indexing and abstracting; by making texts readily searchable through optical character recognition; and by creating conceptual links within documents and collections of documents, using full-text search software for browsing these files. Image files can be made more valuable either by digitizing bit-

mapped images for dissemination on CD-ROM, or through recording and indexing the images on videodisc.

- Communications. Exchange of information is essential to the operation of any research enterprise. Creation of a library-based information clearinghouse is planned, with staff devoted to facilitating communication on global change. Such a clearinghouse will establish and maintain one or more electronic bulletin boards devoted to global change topics. It will issue publications with global change information, in hard copy and/or in electronic form, as CD-ROM compilations, for example. A clearinghouse will handle the details of technical conferences and provide opportunities for visiting scholars to carry out library research, from their laboratories.

- Integration. The clearinghouse will also develop and integrate the components of a user-oriented knowledge access system, serving all the participants in the global change program. One extremely important requirement for such a system is the ability to provide access to communications networks, together with participation in organizational networks of users. Among other components of such a system would be an electronic "gateway" from users to multiple information sources located on different networks and using nonstandard query languages. Also useful would be specialized workstations, built with appropriate hardware and software; user access aids such as directories, thesauri of terms for searching materials related to global change, and natural language query software; and the digitized text and images of useful publications.

- Strategies. Different strategies are appropriate for management and operation of different data management tasks within USDA. Data bases will be built by individual agencies to meet specific needs. Conversely, centralization of data indexes is required to maintain the overall system, from inventorying datasystems to increasing value of system products, establishing communications capabilities and integrating components of the system. USDA seems to be a logical location for this function, provided that funding and staffing can be made available.

Finally, a coordinating committee representing all participating USDA agencies is proposed to provide policy guidance both to the individual agencies and to the overall system operator. In addition to coordinating global change activities within the Department, this committee would be responsible for coordinating with external groups such as the Interagency Working Group on Data Management for Global Change, as well as with international groups working in this same area.

The goal is to create an appropriate data management program to support USDA efforts related to global change.

IV. EDUCATION

Formal and informal environmental education responsibilities are shared by many branches of Federal, State, and local governments. The Departments of Agriculture, Education, Interior, and Energy, and the Small Business Administration; the Environmental Protection Agency, and others will disseminate information and help develop human expertise to effectively address the many issues related to global change.

USDA has significant responsibility for formal education efforts in the food, fiber, and agricultural sciences. This has focused on the availability of scientists and quality of scientific and professional expertise. USDA is closely associated with State colleges and Land-Grant universities in research and extension and has been developing these associations through its Office of Higher Education. Informal education efforts are also provided by the USDA Extension Service and the States as part of the national Cooperative Extension System.

Formal Education Programs

The Higher Education Program administers three major programs that will focus on global change issues.

- The USDA National Needs Graduate Fellowships Program will fund fellowships in the area of environmental science and conservation management.
- The Competitive Institution Challenge Grants Program will provide funding for curriculum design and materials development, faculty preparation and enhancement, teaching methods and teaching systems, student hands-on learning, student recruitment and retention, and scientific instrumentation for teaching.
- The 1890 Institutions Capacity Building Grants Program will provide funds to develop enhanced abilities in environmental education programs relative to global change.

Informal Education Programs

Each of these programs will contribute to the goal of developing human resources. Additionally, the Cooperative State Research Service will increase the amount of funds competitively awarded for recently graduated scientists in the disciplines related to depletion of ozone.

USDA includes a network of Federal, State, and county faculty dedicated to providing current, research-based information to the public. Educational programs developed at the Land-Grant universities are implemented on either a statewide or county-by-county basis. USDA provides Federal funding that enables the States to meet national objectives and local needs.

Education is the essential element for understanding the issues associated with global change. If the issue is to be effectively understood, it must be addressed at all levels. Continuing and informal education programs are seen as a force for increasing understanding and changing behavior as needed. The goal of a strategic plan for education is to create an aware, educated, and motivated citizenry capable of acting to limit, mitigate, and adapt to global climate change, as needed. With this in mind, USDA will:

- Use research about attitudes and behavior to determine local and national needs, identify primary and secondary target audiences, and enable the setting of realistic goals.
- Establish a clearinghouse for information about global climate change for educators, researchers, administrators, government, the public, etc.

- Develop strategies that foster community involvement and that focus on behavior modification that will help resolve all environmental issues and concerns with an emphasis on the importance of individual actions.

V. ASSESSMENTS

Purpose and Scope

A major objective of the USDA Global Change Program is to assess the present and predict the future health and well-being of global resources. The assessment will provide a scientific framework for developing individual and public policy options and provide information that individuals, communities, and nations may use to formulate responses to global change. Reliable information is essential for responsible resource stewardship and in the United States, USDA agencies have been granted legislative authority to develop periodic resource assessments. Components of the assessment will include: (1) description of basic trends in quality of the resources and types of land use, (2) description of current conditions, (3) projection of trends within the context of a changing environment, (4) outline of potential strategies for responding to these projections, and (5) defining the uncertainties associated with all aspects of the assessment. Global change, however, is of such unprecedented complexity that considerable integration of existing assessment capabilities will be required.

Perceptions of change are often influenced by seasonal to decadal regional weather trends, such as the droughts of the 1930's, 1950's, and 1970's or the hot, dry years in the 1980's, and local to regional environmental changes, such as the effects of acid rain or urban smog on vegetation. Increased understanding of the Earth system has highlighted the need to consider long-term changes, such as those associated with global environmental change. There is great uncertainty in the projections of the effect of environmental change on local ecosystems. However, long-term land use and management trends and local topography will play a major role in the change of the landscape. For example, changes in precipitation and temperature may affect the geographic distribution and the management of some agricultural ecosystems. Changes in the occurrence and distribution of fire, insects, and disease will impose new and different stresses on natural and cultured ecosystems. There is a need to assess how global change affects our renewable resource base of soil and water from forest, range, agricultural, and other associated ecosystems. Reliable estimates of the scope and rate of environmental change are needed at many decision levels within society: individuals (for example, foresters, ranchers, and farmers), industry (for example, processing, storage, and transportation), and governments (for example, resource managers and policymakers).

The assessment process is the distillation and integration of the results of research and resource monitoring into a product meant to provide the analytical base for specific policy questions. Ecological, silvicultural, agricultural, and economic models will provide the tools for accomplishing this synthesis and integration.

The first step in the process will be to assess probable environmental change using models developed by the U.S. Global Change Research Program.

The second phase of the assessment will establish linkages between environmental changes and likely changes in terrestrial and aquatic systems and will be used to identify the positive and negative feedback mechanisms between the biological and physical environments and the climate.

The third major phase of the assessment will be to trace how climate and biophysical changes affect human populations and associated communities and, importantly, to determine how altered human actions influence climate change. Market analysis can measure how climate

change affects the economy. Analysis of human effects will, however, go beyond market effects to include the full spectrum of human interactions with the environment.

The assessment will identify various policy options for government officials and examine these options as alternatives for risk management. This is the fourth and final step of the assessment, and it is the step that brings the assessment process full-circle. The policy options will be examined for their ability to alter human actions. Altered human actions, in turn, will be studied as a means of conserving resources, or mitigating or limiting emissions of greenhouse gases. These will be fully integrated, among the Federal agencies through the Mitigation and Adaptation Research Strategies (MARS) Program of the Committee on Earth and Environmental Sciences (CEES) under the Federal Coordinating Council for Science, Engineering and Technology (FCCSET).

The scientific uncertainty associated with the rate and amount of climate change is likely to be so great that reliance solely on the predictive capability of existing computer climate models has very little value. Thus, the potential effects to agricultural and natural resources caused by increases in the atmospheric composition of greenhouse gases and the secondary effects on human beings must be analyzed within a risk analysis framework dealing with probabilistic (stochastic) ranges rather than deterministic results.

The changes examined in the assessment are likely to occur gradually over relatively long time periods. Therefore, assessment will adopt a long-term perspective. Also, the scope of climate change is so large that the effects on one sector of the economy cannot be considered separately from the entire economy. For example, it will not be realistic to examine only climate change-induced wheat production and markets within the United States without also examining wheat production in the rest of the world.

Resource Monitoring

Monitoring is the long-term, periodic measurement of selected physical and biological variables for establishing baselines and detecting and quantifying change over time. It forms the foundation on which two of the components of the assessment are made: (1) description of basic trends, and (2) description of current conditions.

Climate Scenarios

The Global Change Assessment will develop, in coordination with researchers involved in climate and Earth systems research, scenarios designed to span the range of potential changes in temperature, rainfall, and storm patterns globally and regionally. Comparison of the output from existing general circulation models has shown some agreement in the prediction of an increase in the average global atmospheric temperature with a probability of occurrence ranging from 50 to 70 percent. USDA, in cooperation with climate and Earth systems researchers, will compare model output for several scenarios for stabilizing the atmospheric composition of greenhouse gases to test the scientific certainty of future climate projections.

The Global Change Assessment will develop probabilities of occurrence associated with the spectrum of climate change scenarios. These probabilities of occurrence will provide information for use in comparing how possible changes in climate would affect forest, range, and crop ecosystems.

Ecological Consequences

The Global Change Assessment will analyze USDA policies associated with renewable resource management and alternative soil and water conservation practices. The effects of these programs on the biological and physical components of the forest, range, and crop ecosystems will be evaluated so that the appropriate future policies and programs of the Department can be determined. Analysts associated with the Global Change Assessment will work with the policymakers to determine how these effects will influence factors that cannot be directly linked to projection models.

- Linking climate, ecosystem, and management/policy models. The Global Change Assess ment will translate the current understanding of climate-affected biological and physical processes into an assessment of the effects of these processes on management of agricultural, forest, and range ecosystems. In addition, it will evaluate the effects of managing agricultural, forest, and range ecosystems on climate and the physical environment.
- Links to policy models. Management of forest, range, and agricultural ecosystems is motivated by the values, goals, and objectives of human populations. USDA will determine how future climate changes will affect humans through effects on agriculture and forestry, and how altered agricultural and resource management activities will affect climate change. Changes in human behavior affecting supply and demand of renewable and agricultural resources will affect the appropriateness of resource and commodity conservation programs and the management of forest, range, and associated lands. Such changes will be included in models developed for policy analysis.

Linkages Between Ecological and Supply/Demand Models

Both the Resources Planning Act (RPA) Assessment and the Resource Conservation Act (RCA) Appraisal have developed models and methods for analyzing the supply and demand for various agricultural, range, and forest resources. The USDA Global Change Assessment will also be concerned with analyzing supply and demand. Thus, many of the models developed for use in the RPA Assessment and RCA Appraisal will be appropriate starting points for these analyses. However, linking the models to ecological change is necessary to ascertain the effects of global change.

Demand factors that are considered in the RPA/RCA analyses include the size and location of populations, gross national product, personal disposable income, institutional and technological change, energy costs, and capital availability. Consideration of these factors will be important in understanding how climate change will alter the demand for forest, range, and agricultural outputs. There will be direct and indirect effects on all sectors of the food and fiber system, including storage, processing, transportation, and marketing.

Examination of Management Options

Environmental changes present new challenges for managing silvicultural and agricultural production systems. Future resource management options will be a function of human actions and demands, as well as environmental change. Alternative levels of production will be realized under different policies. Three broad options are: (1) conservation of existing natural resources and agricultural potential, (2) mitigation of factors with the potential to affect global change, or (3) adaptation of agriculture, range, and forest ecosystem management to the changing environment. A combination of any or all of these is also possible. Different methods will be used to implement any one of these three policy options or a combination of these three policy options. The role of the Global Change Assessment is to project how different policies will affect resources. It will involve examination of questions such as how much and which forest, range, and agricultural land should be managed for production. These and many other

alternatives will be developed and evaluated in cooperation with development and application of global change prediction models. It is important that management options also be evaluated in light of information gathered during the assessment and monitoring phases and that the predictive models use the most current data.

VI. RESPONSE STRATEGIES

USDA policies on global change will need to recognize that global change must be addressed from an international perspective. Industrialized nations are currently the largest contributors of greenhouse gases and may be able to mitigate some of the increasing atmospheric composition of greenhouse gases through energy conservation and other efforts to reduce emissions. As developing nations industrialize, their per capita energy consumption will increase with their standard of living. Thus the global emissions of greenhouse gases may continue their upward trend. Therefore, we are committed to some global change. The total effect on global climate change, however, still has significant room for scientific debate. As a result, USDA policies must address both mitigation and adaptation. USDA must also take into account both the national and international economic consequences of its policies on the food and fiber security of the nation and the world. It will not assume such efforts in isolation, however, but as a full member of the Mitigation and Adaptation Research Strategies (MARS) working group of the Committee on Earth and Environmental Sciences (CEES) of the Federal Coordinating Council for Science, Engineering and Technology (FCCSET).

Uncertainties in our scientific understanding of global change are likely for some time in the future. Any assessment of global change affecting the security of United States food and fiber will obviously contain uncertainties. The probabilistic nature of the food and fiber production projections dictates that the USDA must address policy options and possible responses from the standpoint of risk management. Such a view is consistent with the risk assessment approach outlined in the "Assessments" chapter of this plan.

Policies that address global change problems will almost never lead to a specific solution for each specific problem. Agricultural and forest systems are constantly bombarded with a number of different stresses: air pollution, drought, fire, insects, and disease outbreaks, and in a changing climate. Each organism on the farm or ranch or in the forest reacts differently to these physical and biological stresses; attack and defence balances are constantly changing. USDA policies must focus on ecosystems, and policies for the individual components of agriculture and forestry must be examined from this broad perspective. Agricultural, range, and forest policies of the future will need to be examined for their possible effects on global change. Most global change policies or policies that indirectly address global change will have economic and social costs. Criteria for ranking alternatives will be needed. USDA will need to develop procedures to evaluate whether its policies might influence global change.

At a minimum, the evaluation procedures should include the following considerations:

(1) Does the strategy represent sound policy independent of whether it influences global change? If the policy leads to sustainable agricultural and forest systems (sound policy) whether or not global climate change occurs, then the policy may well be one we follow in any case.

(2) How certain are we that the action, if taken, will be beneficial? The key point of this criterion is to evaluate the uncertainties inherent in global change predictions, how those uncertainties affect the uncertainties of the effects, and how confident we are in taking action in light of those uncertainties. This point is intended to quantify the risks associated with a proposed action.

(3) What are the costs of the proposed strategy—socially, economically, and environmentally? This part of the evaluation considers how much a particular reduction in green house gas emissions will cost, and how it will affect other resources, such as water, forage for wild and domestic animals, aquatic ecosystems, and genetic diversity.

(4) Is the policy politically feasible and will the public support it?

USDA will need to recognize that policies will be proposed by several organizations and agencies. These policies will directly affect agriculture and forestry. In such circumstances, USDA will need to take an active role in establishing policy related to global change rather than simply react to others' policies.

Global change policy decisions will include limitation and mitigation measures—including those, for example, to use forests as temporary carbon sinks—and adaptation designed to limit negative consequences of global change. The policies may have immediate environmental benefits and contribute toward stabilization of atmospheric gas composition over the long term.

United States decisions about agriculture, range, forestry, and other natural systems management must recognize that domestic policies directed toward other sectors of the economy, or toward policies of other countries, have indirect effects on U.S. agriculture and forestry. The converse is also very true. For example, slowing tropical deforestation may reduce timber supply and increase demand for U.S. timber and wood-based fuels. Greater reliance on biomass energy will place competing pressure on land currently used for agriculture, range, and forestry, and on land managed in its preserved state. Fossil fuel taxes to limit carbon emissions would increase energy and fertilizer costs to farmers. These policy considerations are summarized in figure 1.

Emergency Response Systems

While much of this chapter is aimed at long-term USDA responses and policies related to global change, it is imperative that USDA recognize that there is also a need for strategic planning to address short-term critical problems of global change. For example, we might experience increases in severe weather such as drought or flood. Also, weather-related disturbances such as insect and disease outbreaks or forest fires might increase in occurrence and severity. We will need to consider these changes, and design ways to offset the effects and preserve the food and fiber security of the Nation.

The key elements of response to global change include: (1) improvement in scientific understanding, and (2) a framework for making risk assessments and decisions. The previous chapters have summarized ways to improve scientific understanding of global change and to assess what global change means for society. This chapter explains how departmental management and policy decisions will be reviewed for all sectors of the U.S. food and fiber enterprise and each sector's potential sensitivity to global change. The principal strategy involves an initial thorough review of departmental policy with periodic reassessment and recommendations for action. Coordination will be maintained with other departments and Federal agencies through the FCCSET Committee on Earth and Environmental Sciences (CEES) working groups and with international organizations, such as the Intergovernmental Panel on Climate Change (IPCC).

Policy Instruments and Global Change

A wide range of policy instruments exists to maintain the health of the agriculture, range, and forestry sectors, ensure adequate domestic food supplies, provide food assistance to the Nation's poor, aid areas abroad that have food shortages, provide education and technical assistance, and improve the technological base on which agricultural production rests.

Many of the effects of global change may require long-term permanent adjustments in the location of agricultural production, the extent of cropland, and the technologies and production practices used. Thus, the focus of global change policy will involve those programs that shape the technical capabilities of the food and fiber production sector and its ability to respond to changing conditions. Therefore, the adequacy of agricultural research and development, technology transfer, and education will be assessed in light of a potential for changes in resources, and in local and global environments not previously experienced. The extent to which short-term programs affect the ability of the production sector to respond to long-term changes will be assessed. These short-term programs include commodity, price, subsidy, and tax policies, acreage programs including the Acreage Reduction Program (ARP) and Conservation Reserve Program (CRP), trade policy, regulatory policy regarding food safety, new product testing and development, and ARP and CRP transportation adjustment and rural development programs.

In particular, the Department's ability to respond to emergencies and the adequacy of commodity stocks and reserve capacity will be considered.

Global Change Policy Review

To firmly incorporate global change considerations into management and policy decisions, the Department will conduct a thorough review of existing policies that affect global change policies, identifying the types of changes that might be considered under various global change scenarios and recommending such changes to the Secretary's Policy Coordinating Council. Such a strategic assessment will provide a basic set of approaches for addressing global change issues as scientific understanding and the accuracy of predictions improve.

The Department will establish a comprehensive policy review cycle, assessing scientific findings and predictions and developing a set of recommendations for how agencies may respond within existing program authorities. It will also find ways to strengthen agencies' authorities in addressing agricultural consequences of global change.

Figure 1.

U.S. AGRICULTURE AND FOREST POLICY: EXAMPLES OF MITIGATION AND ADAPTATION ISSUES RAISED BY GLOBAL CHANGE

I. AGRICULTURE AND FORESTRY

A. UNITED STATES

1. Mitigation - long-term
   Sustainability of U.S. agriculture
2. Mitigation - short-term
   Sequester CO_2 through resource management
3. Adaptation - long-term
   Expand commodity surplus storage reserves
4. Adaptation - short-term
   Establish agricultural water use efficiency standards
5. Adaptation - long-term
   Improve the capacity of the Nation's soils to absorb and store water and carbon

B. INTERNATIONAL

1. Mitigation - long-term
   Reverse tropical forest land conversion
2. Mitigation - short-term
   Support rice farming systems research to reduce methane
3. Adaptation - long-term
   Establish international genetics programs for stress tolerance in trees and crops

II. OTHER SECTORS

A. UNITED STATES

1. Mitigation - long-term
   Alternative sources of non-fossil energy
2. Mitigation - short-term
   Increase farm energy efficiency
3. Adaptation - long-term
   Eliminate food and fiber trade barriers

B. INTERNATIONAL

1. Mitigation - long-term
   Methane production for energy cogeneration
2. Mitigation - short-term
   Industrial technology transfer programs

APPENDIX I

USDA Monitoring Programs

The Forest Service currently has three major monitoring programs directed at forests and related ecosystems. These include: (1) Forest Inventory and Analysis, (2) inventory activities associated with the management of national forests throughout the National Forest System, and (3) the insect and pathogen surveys of State and Private Forestry.

Forest Inventory and Analysis (FIA) is the only organization, public or private, that conducts periodic forest resource inventories and evaluations. The mission of FIA is to inventory and evaluate past trends, current status, and potential supply, use, conditions, and productivity of the renewable natural resources of all forest lands in the United States, both public and private. For most regions of the United States, FIA has developed data bases of forest resources that span 30 years, with complete inventories conducted approximately every 10 years. Multiresource inventories are planned and conducted to provide current information on the kind, amount, condition, ownership, and use of, and trends in, renewable forest resources. When necessary, special analyses of specific resource issues and concerns are conducted more frequently. Forest industries, financial consultants, and State resource planners use forest inventory data, monitoring surveys, and results of subsequent analyses as a basis for industrial expansion decisions, financial investment analyses, State forestry programs, and public and private forest policies.

Through the National Forest System, the Forest Service conducts integrated inventories of all renewable resources on national forests and grasslands. The primary focus of past inventories has been on timber. Inventories of wildlife and fish habitat, water quality and watershed condition, soils, and recreation opportunities and use are receiving increased effort. However, an additional important aspect is monitoring how resource management actions affect the various resources. Annually, about 10 percent, or about 16.5 million acres, of the forested lands on national forests are inventoried. This information, along with information about other renewable resources, is used in developing forest plans under the National Forest Management Act (1976) planning process and in the Resources Planning Act Assessment. Under this process, each of the 123 national forest administrative units establishes new allowable sale quantities and outlines timber management activities for the next 10 to 15 years.

The National Forest System also monitors important physical environmental variables as part of the soil, water, and air management programs. The objectives of these programs are: (1) to provide water of suitable quality and quantity to meet public needs and resource requirements, (2) to ensure the continued production of natural resources by protecting and enhancing soil productivity, (3) to protect National Forest System lands and adjacent watersheds from adverse effects of air pollution, and (4) to provide weather information for resource management and protection. The Forest Service, in conjunction with the Soil Conservation Service, conducts soil inventories on national forests and assesses the condition of watersheds for maintaining water quality, timing of water runoff, and preventing floods. Air quality is monitored at 38 sites nationwide, and guidelines have recently been developed for (Class I Airsheds) assessing air quality-related values on 88 national forest wilderness areas. The weather program coordinates the management of about 300 Forest Service remote automatic weather stations.

The Forest Service is responsible for protecting the Nation's forests, both public and private, from extensive damage by insects and pathogens. Surveys are an essential first step in this

process. In 1988, the Forest Service conducted aerial and ground surveys to detect and evaluate vegetation damage or pest populations on 133 million acres of Federal lands and assisted State forestry organizations on an additional 460 million acres of State and private lands. Annual reports based on these surveys provide a historical record with which to evaluate future pest activity.

The Forest Service has developed and begun implementation of a plan to enhance and maintain the health of the Nation's forests. The term "forest health" describes forest ecosystem resilience and productivity relative to public values, needs, and expectations. Forest health monitoring addresses forest health relative to effects of both naturally occurring factors such as fire, forest pests, forest succession and drought and unnatural biological and human-caused factors such as introduced pests, air pollution, and increasing atmospheric composition of greenhouse gases. Existing activities of Forest Inventory and Analysis and Forest Pest Management programs form the core of this initiative.

The Resources Inventory Division of the Soil Conservation Service provides data on the status, condition, and trends of soil, water, and related resources to data users. The programs involved include the National Resources Inventories, the Important Farmlands Inventory, Snow Surveys and Water Supply Forecasting, the Wind Erosion Conditions Inventory, and Short Duration Phenomenon reports. Each of these is of potential value for resource monitoring with respect to climate change. As these have been in effect since the early 1970's (or longer in some instances), significant historical data already exist.

National resource inventories have been conducted at 5-year intervals since 1972. Data collected during these inventories include: (1) soil characteristics and interpretations, (2) land cover, (3) land use, (4) erosion, (5) land treatment, (6) conservation treatment needs, (7) vegetative conditions, and (8) potential cropland. These data will provide information on potential land bases, land use changes, and productivity of soil and vegetation as affected by, or interacting with, global change.

The Important Farmlands Inventory details the status of prime, unique, and additional farmlands of State and local importance. Maps showing the extent of land in each of these categories have been completed for 18 States, for a total of 1,200 high-priority counties. This information will aid in assessing the effects of global change on agricultural productivity.

Snow Surveys, and resulting water supply forecasts, rely on data from an extensive data collection network consisting of 1,600 manual snow courses and 550 automated sites, 600 stream gauges, 300 reservoirs, and 1,200 precipitation stations. Water supply forecasts are issued cooperatively with the National Weather Service from January through June of each year and are directed primarily at agricultural water users. These forecasts also allow municipalities to plan the management of anticipated water supply early in the year. Such water supply forecasts can be incorporated into the predictive models developed for the global climate change program.

The annual Wind Erosion Conditions Inventory was initiated during the 1930's and is still carried out in the 10 Great Plains States. The purpose of this inventory is to provide information on the status and condition of soil and vegetative resources as related to wind erosion during critical months of the year when wind erosion is a hazard. During the critical

period, from November 1 through May 31, three cumulative reports are prepared on land damaged, crops damaged, land in condition to blow, and conservation measures taken to prevent damage.

The SCS also informs the Department, the news media, and others of relatively short duration phenomena that affect health, safety, and agricultural production. Examples of such phenomena are droughts, hail, floods, hurricanes, tornadoes, volcanic eruptions, prolonged temperature extremes, fire, plant disease, and insect infestations.

Once the resources inventory data are made available to users, it is important that the data be accurately interpreted and properly understood in terms of data element definitions, statistical reliability, internal integrations, and linkages with other data bases. The Resources Inventory Division works closely with agency policymakers and outside researchers in projects that involve the use of resource data for analyzing soil, water, and related resource issues and concerns. Staff are currently investigating ways to increase the use of remote sensing and to establish the Earth Cover Identification System as the data collection system for national resources inventories, which would improve accessibility and utility of the existing data systems. A geographic information system will also be implemented and will provide the ability to look at numerous resources simultaneously across large geographical areas.

Precipitation and Particulate Monitoring and Research. A 200-site network established in 1977 will continue to be used to collect data on precipitation and atmospheric deposition. The network involves collaboration of six Federal agencies and the Land-Grant university system. Recently, the Environmental Protection Agency added ozone monitoring instruments to selected sites. This network will be enlarged to include monitoring for UV-B radiation and trace gases at selected sites established by USDA.

APPENDIX II

USDA Global Change Responsibilities

The agencies participating in this strategic plan are the Agricultural Research Service (ARS), the Cooperative State Research Service (CSRS), the Economic Research Service (ERS), the Extension Service (ES), the Forest Service (FS), the Soil Conservation Service (SCS), the World Agricultural Outlook Board (WAOB), the National Agricultural Library (NAL), and the Office of Energy (OE).

Together, these agencies form a team capable of addressing the major components of the agricultural, range, and forest ecosystems as related to global change issues.

ARS

The Agricultural Research Service global change research program focuses on understanding the physical, chemical, and biological processes linking the performance of the agricultural system to environmental variables expected to be affected by global change. These variables include radiation intensity and quality, atmospheric trace gas concentrations (especially carbon dioxide and ozone), temperature, humidity, and rainfall. This understanding is captured and quantified in system models. These models serve as a framework to organize the experimental data and mathematical descriptions of various climate-related processes. This is provided by the research of individual scientists from the many disciplines required, and also serves as the foundation for developing predictive tools to serve as decision aids for agricultural and natural resource managers. These tools will serve not only to predict how global change affects the agricultural system, but also to predict how alternative agricultural management practices affect factors that in turn affect global change.

SCS

The Soil Conservation Service, through its lead role in the National Cooperative Soil Survey, has collected, analyzed, and mapped, and inventoried most of the privately owned land in the United States. Various soil data bases are significant for testing, evaluating, and extrapolating simulation modeling results to geographical locations of interest. In the United States there are over 16,000 soil series and almost 60,000 soil map units. The soil data bases are being restructured to enable easier access and application. Work is underway on national and international soil maps and a reference soil classification system to support global interpretations such as degradation, productivity, and fragile lands. Additional work on quantitative models of soil formation involves both landscape-forming processes and soil-forming processes that relate to historical climatic changes.

A statistically reliable inventory of U.S. natural resources (soil, land, water) is conducted on a 5-year cycle and its assessment is used to formulate policies affecting future land uses. A state-of-the- art remote data collection system (SNOTEL) is employed in obtaining seasonal and annual data on snow fall, pack, and water content in the Western United States, this program contributes to water forecasting in the United States.

CSRS

The Cooperative State Research Service effectively links the resources of the Nation's agricultural experiment stations. Located in all 50 States, the District of Columbia, Puerto Rico, Guam, the Virgin Islands, and Micronesia, these agricultural experiment stations provide the expertise of university scientists in developing the basic theories and the technology needed to predict and characterize global change and its consequences to agriculture.

In the crucial forestry research and educational field, the McIntire-Stennis program includes 61 State universities where research on all phases of forestry is carried out and graduate students are prepared to solve the environmental problems of the future. Also, the Evans-Allen program involves the 17 traditionally black Land-Grant Institutions and Tuskegee University.

The Competitive Grants Program of the Department is open to an even wider variety of research institutions in the United States. This program has assembled the best collection of expertise the world has thus far developed for dealing with agricultural and environmental problems.

University scientists have been organized in a Regional Research Program for several years to work specifically on agricultural climatology and crop plant and forest responses to environmental influences, including carbon dioxide, ozone, and other gases, temperature, light, and humidity. Experiment stations have programs in genetics and biotechnology to develop crops, animals, and forest trees adapted to whatever conditions will be present in the future.

Another aspect of these university research programs is that they are the source for the education of the coming generations of agricultural research scientists. There is no doubt that there will be an increased need for highly educated agricultural research scientists and engineers to ensure future food and fiber supplies.

ERS

The Economic Research Service provides the primary departmental capability for economic analysis of agricultural commodity markets, rural economic development, commodity trade, advancing agricultural technology, and resource use. To carry out this research focus, the agency maintains a number of assessment, simulation, and predictive models capable of analyzing agricultural sector response to changing policy, environmental and resource constraints, technologies, and macroeconomic conditions. Staff capabilities include timely analysis of agricultural policy issues, adaptation of existing models, and development of new models to meet analysis requirements, and management and maintenance of data necessary to carry out research. These capabilities provide a critical link in the analysis of human interaction and response to global change by the food- and fiber-producing sector.

ES

The Extension Service is the educational agency of the Department of Agriculture and the Federal partner in the Cooperative Extension System. The system links research, science, and technology transfer to the needs of people, where they live and work. This nationwide network of professional staff and community volunteers is a unique and integrated partnership involving Federal, State, and county government, research, and agribusiness. This partnership has representation in all of the proposed expert groups and can function to transfer technology.

The ultimate effect of economic and agricultural research will be judged by the success with which those policies and practices are implemented by the citizenry. Only through changes in the way people think about and value the environment will real changes be accomplished that may prevent additional environmental degradation. Opportunities are available for the Cooperative Extension System to work with diverse groups in the development of site-specific recommendations, based on research knowledge, which are profitable, environmentally sound, and socially acceptable. Global change may result in many shifts in rural communities and in the structure of those communities. Cooperative Extension networks maintain the capacity to aid in coping with the social and educational aspects of such shifts.

FS

The Forest Service has recently developed a comprehensive plan for dealing with forest productivity, health, and diversity in a changing environment. The Forest Service Global Change Research Program is based on an integrated, multiple scale, multiple stress approach to 1) understanding effects of global change on forest and related ecosystems; 2) understanding forest ecosystem effects on global change; and 3) monitoring and modeling the above effects for assessment, prediction, and policy determination. Its research will also focus on the development of a wide range of predictive models and on acquiring the data sets to operate them. By virtue of the large reserves of forest and range land directly managed by this agency, the decisions made will have significant impact. One of the difficulties faced in forest management is a long timelag between changes in climate and biosphere responses. Some forest stands are over 100 years old. Not only is the Forest Service faced with assessing the potential impact of future changes, it must also assess how changes in atmospheric pollution to this point will affect future forests. The forests that exist now were produced under conditions that differ from those of today. Disturbance phenomena such as fires, insect and disease outbreaks, windstorms, and floods are having an expanded impact on forest ecosystem change. Even without future changes, tomorrow's forests could, therefore, be quite different.

Forest Service research will contribute significantly toward the capability to predict species distribution for future climate scenarios. It will also contribute toward an assessment of the Nation's water supplies that depend on vegetation and soil properties within the lands and forests managed by this agency. The long-range resource management program will focus on development of: (1) physiologically based models to predict the effects of global change, (2) models showing the biophysical effects of such changes, (3) methods to link these models, and (4) economic impact and risk assessment models.

WAOB

The World Agricultural Outlook Board utilizes a network of cooperating USDA agencies for estimating the world's agricultural production on the basis of environmental data from many sources. This agency's data bases and analytical techniques are a substantial resource for predicting world crop production under a range of climate scenarios. The demand for U.S. agricultural production will always be sensitive to production in other countries. Global change could cause significant decreases in agricultural production in some countries and increases in others. A sea level rise, for example, would nearly eliminate food production from low-lying countries such as Bangladesh.

OE

The Office of Energy is responsible for leadership, oversight, and coordination of all energy activities and development of policies and strategies concerning energy and energy-related programs and resources of the Department.

Global change issues have several connections to agriculture and energy issues. The Office is responsible for providing information in support of research that other USDA agencies are conducting on global change, helps to coordinate global change activities with other departments, and assists in developing policy papers and responding to policies proposed by Congress and others.

NAL

The National Agricultural Library is responsible for coordinating, compiling, and disseminating information on global change. The National Agricultural Library has the capability to develop and make available computerized systems enabling policymakers, administrators, researchers, educators, extension staff, producers, and the public to access and use with ease all the knowledge in this field. The National Agricultural Library makes this possible by creating electronic networks of institutions, disseminating information and distributing copies of documents in electronic form; building electronic files in all media for all types of information—scientific data, text, images, and citations—and increasing the value of these files through indexing, abstracting, building electronic links within documents and among collections of documents; and by creating directories of information sources. NAL facilitates user access to knowledge, by developing specialized workstations, expert systems, sophisticated search software, and gateways to the networked files and integrating these components within a powerful, but user-friendly, system.